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GB 0416187.3

By virtue of a direction given under Section 30 of the Patents Act 1977, the application is proceeding in the name of:

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[ADP No. 08953010001]

Patents Form 1/77

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1. Your reference — P1243GB00

2. Patent application number *(The Patent Office will fill in this part)* — 0416187.3 — 20 JUL 2004

3. Full name, address and postcode of the or of each applicant *(underline all surnames)* — Formpave Holdings Limited, Staverton Court, Staverton, Cheltenham, GL51 0UX

   SECTION 30 (1977 ACT) APPLICATION FILED 17/9/04

   Patents ADP number *(if you know it)* — 846531 2001

   If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — A HEAT EXCHANGE STRUCTURE

5. Name of your agent *(if you have one)* — K R Bryer & Co

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* — 7 Gay Street, Bath, BA1 2PH

   1077002

   Patents ADP number *(if you know it)*

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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   a) any applicant named in part 3 is not an inventor, or
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Claim(s)	6
Abstract	
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11. I/We request the grant of a patent on the basis of this application.

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Date 19 July 2004

12. Name and daytime telephone number of person to contact in the United Kingdom: Dr Matthew Greenwood – 01225 428877

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A HEAT EXCHANGE STRUCTURE

The present invention relates generally to a heat exchange structure and particularly to a heat exchange structure intended for exchanging heat within a subterranean environment. One particular application of such a heat exchange structure is as part of a heat pump system in which the heat exchange structure is used to provide cooling or heating, for example to a building, depending on the direction of operation of the heat pump.

It is known to form deep vertical bores in the ground to house pipes bearing a heat exchange fluid for bringing the fluid into thermal contact with the ground, which can then act either as a heat source or a heat sink. The deep vertical bores are particularly aimed at seeking to contact the water table so that water surrounding the pipes can be used as a secondary heat exchange liquid to ensure good thermal contact between the heat exchange liquid within the pipes and the ground. As an alternative it is also known to lay pipes horizontally in ponds or lakes, or directly into the ground where the water table is high enough to allow contact with water.

The known systems therefore have the limitation that they must rely on the natural presence of water, such as the water table or a lake, to function. In the case of a horizontally laid pipe system relying on the presence of the water table, if the water table dropped below the level of the pipes then the heat exchange efficiency would be dramatically reduced. Digging deep horizontal trenches to accommodate pipes to overcome this problem is not practical.

The present invention seeks to address the problems with the known heat exchange structures.

According to a first aspect of the present invention there is provided a heat exchange structure comprising: a substantially water impermeable channel for collecting water; and one or more heat exchange pipes passing through the channel carrying a heat exchange fluid.

The present invention is based on the desire to be able to establish a heat exchange relationship involving water regardless of the level of the water table. Accordingly a sump-like arrangement is provided by the channel which collects and holds water, effectively creating an artificial water table for the heat exchange pipes to pass through. This would allow horizontally laid pipes to be used even in circumstances where no contact with the water table is available.

The heat exchange structure may be located in a subterranean environment. Accordingly the channel may be a subterranean channel buried together with the heat exchange pipes.

A heat exchange structure positioned outdoors is able to take advantage of rain fall to collect water for use in the heat exchange process. However, in order to prepare the structure for immediate use the channel may be artificially filled with water. Subsequently the channel will be kept full naturally by collecting rain water from above.

In order for the structure to function efficiently the channel must be substantially impermeable to water. The structure may include a substantially water impermeable trough member which comprises the channel or forms a liner therefor. Accordingly the trough member may simply rest on a surface, or may line a pre-formed channel.

The trough member may be formed from a material having a high thermal conductivity so that the channel does not impede the heat exchange process.

The trough member may comprise a rigid plastic trough or alternatively may comprise a flexible plastic liner.

Preferably the channel and/or trough member is closed at each end to hold trapped water indefinitely rather then just serving as a temporary obstacle.

The channel may contain only water; or for subterranean heat exchange pipes the channel may simply be filled in with earth once the pipes have been laid. Alternatively the channel may contain particulate material, such as crushed rock, which acts as ballast and allows water to permeate easily into the channel from above. In addition, the particulate material allows for more efficient transfer of heat than just soil.

The channel may be overlaid by a water permeable layer of particulate material, such as crushed rock to increase the permeability of the area above the channel and maximise water collection.

The size of the particles overlaying the channel may be greater than the size of the particles contained in the channel.

A water permeable wear surface may be formed over the channel. In one embodiment the wear surface is formed directly over the channel, whereas in other embodiments the surface is formed over the water permeable layer of particulate material if present. The permeable wear surface may comprise, for example, a pavement structure. Permeable pavement and sub-base designs are already known and would be particularly suitable for use in conjunction with the heat exchange structure of the present invention.

In order to increase the heat exchanging capacity of the structure there may be a plurality of heat exchange pipes provided in the channel. In order to maximise the efficiency of heat exchange the plurality of heat exchange pipes may be mutually spaced within the channel. The spacing of the pipes may be achieved by the particulate material in the channel. The material can act as a framework or separation grid to hold the pipes away from each other so that each can be in separate and maximum thermal contact with the surrounding water which fills the channel in use of the system.

Whilst in theory the depth of the pipes can be at any distance below the surface of the ground, in one embodiment the pipes are buried approximately 1.5m below the surface, as this requires the excavation of only a shallow trench to accommodate or form the channel.

In order to improve the efficiency of water collection in the channel there may be provided one or more diverter members positioned above the channel for directing water into the channel. In one embodiment the directing means comprise sheets of water impermeable membrane arranged to funnel water into the channel. The diverting members serve to increase the area of earth above the channel from which water can be collected and stored.

The heat exchange structure may further comprise a unidirectionally water permeable layer positioned at ground level above the channel. The water permeable layer allows water to pass into the ground above the channel but prevents evaporation thereafter so as to maximise the amount of water collected in the channel.

The unidirectionally water permeable layer may comprise a fabric such as a geotextile or membrane, for example Imbitex.

According to a second aspect of the present invention there is provided a method of forming a heat exchange structure, comprising the steps of: providing a substantially water impermeable channel for collecting water; and passing one or

more heat exchange pipes through the channel for carrying a heat exchange fluid in thermal contact with water in the channel in use of the structure.

Accordingly, formation of the structure may involve excavating a shallow area to form an elongate trench closed at both ends which is, or is modified to be, impermeable to water by any convenient means such as by compaction of the surrounding earth or by providing a liner, coating or other trough-like member.

The method may further comprise a step of filling the channel with particulate material and this may be followed by the step of overlaying the channel with a water permeable layer of particulate material. The particulate material used to overlay the channel may be of a greater average particulate size than the material used to fill the channel.

The method may further comprise the step of forming a water permeable wear surface over the water permeable layer of particulate material. In one embodiment this step comprises the installation of a permeable pavement system which allows for the efficient transfer of water down into the channel. The heat exchange structure then comprises a permeable pavement system with a permeable sub-base formed over one or more water impermeable trenches.

The method may further comprise the step of positioning one or more diverter members above the channel for directing water into the channel in use. During the

construction of the heat exchange structure water impermeable diverter members can be installed to funnel water into the channel.

The method may further comprise the step of providing a unidirectionally water permeable membrane layer at ground level above the channel so that water can pass into the heat exchange structure but is prevented from evaporating whilst it remains close to the surface.

According to a further aspect of the present invention there is provided a heat pump system incorporating a heat exchange structure as described herein.

According to a fourth aspect of the present invention there is provided a building which is heated/cooled by a heat pump system as described herein.

The present invention will now be more particularly described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic section of a heat exchange structure formed according to the present inventions;

Figure 2 is a diagrammatic perspective view of part of the heat exchange structure of Figure 1;

Figure 3 is a diagrammatic section of a heat exchange structure formed according to a further embodiment;

Figure 4 is a heat exchange structure formed according to a still further embodiment;

Figure 5 is a diagrammatic section of a heat pump system incorporating a heat exchange structure according to the present invention; and

Figure 6 is a diagrammatic section of a heat exchange structure formed according to a further embodiment.

Referring first to Figure 1 there is shown a heat exchange structure generally indicated 10. The structure 10 is formed from an elongate channel 20 closed at each end and positioned horizontally in the ground 30. An elongate heat exchange pipe 40 for carrying a heat exchange fluid (not shown), such as water, extends from the surface 35 down to the channel 20 and then passes coaxially along the length of the channel before returning to the surface 35.

The channel 20 is formed from a water impermeable material, such as a plastics material, and thus water entering the ground above the channel 20 drains into the channel 20 as indicated by the arrow A. Because the channel 20 is impermeable to water it acts like a sump and is filled with water 45. This means that the section of the pipe 40 passing through the channel 20 is surrounded by water. The structure 10 is buried in the ground 30 so that the channel 20 is filled with earth 30 and the pipe 40 passes through earth saturated with water within the channel. Accordingly, heat transfer between the heat exchange fluid within the pipe 40 and the earth surrounding the pipe 40 is enhanced, because the water 45 within the channel serves as a secondary heat exchange fluid.

Because the channel 20 is filled with water 45 this creates an artificial water table with a level X which is at a much reduced depth compared to the natural water table level Y.

The heat exchange pipe 40 can form part of any system requiring its heat exchanging properties, such as a heat pump.

Figure 2 illustrates the form of the channel, which is shown to comprise a generally U-shape trough which can be easily buried in the ground in an excavated trench. The pipe 40 is shown passing longitudinally through the channel 20.

Referring now to Figure 3 there is shown an alternative subterranean heat exchange structure generally indicated 110. Above ground level 135 is a water permeable wear surface 150 comprising a pavement system made up of a plurality of blocks such as the Aquaflow (RTM) blocks available from Formpave Ltd. The blocks rest on a bed of stones 155 which have an average size of approximately 6mm.

The stones 155 are laid on a membrane 160 which allows water to pass through from above but will not thereafter allow water to pass back, so that water which enters the ground through the membrane 160 cannot evaporate back out of the ground. The membrane 160 may comprise any suitable geotextile or liner product and is laid directly onto the ground surface 135.

Beneath ground level 135 is a water permeable layer of crushed rock known as a sub-base. The particles size of the layer 165 is greater than that of the stone bed 155.

Beneath the layer 165 is positioned a channel 120 of the same general type of that described in relation to Figures 1 and 2 in that it is a generally U-shape plastic box, in this embodiment being approximately 5m long, 600mm high and 250mm wide.

In this embodiment 12 elongate heat exchange pipes 140 pass through the channel and the channel is filled with stones 170 which are of the same general type as the stones used for the stone bed 155. The stones 170 serve as ballast in the channel 140 and also serve to separate and hold the pipes 140 mutually spaced from each other.

Water, usually in the form of rainwater, will enter the structure via and permeable pavement system 150 and then pass through the successive stone layers 155, 165, 170 before becoming trapped within the channel 120 and surrounding the pipes 140. In use of the system the heat exchange fluid carried within the pipes 140 can transfer heat to or from the surrounding subterranean structure of the stone layer 170 and then to the surrounding earth with increased efficiency because the pipes 140 are immersed in water (not shown).

This structure 110 could be formed as follows. First a trench (not shown) is excavated and the channel 120 is laid into the trench. The pipes 140 are laid into

the channel and the stone layer 170 is filled into the channel around the pipes 140 separating them from each other. The layer 165 is then added to the trench above the channel 120. The permeable membrane 160 is laid across the mouth of the trench above the layer 165. The stone bed 155 is then poured onto the membrane 160 and the pavement blocks 150 are laid into the bed 155.

Referring now to Figure 4 there is shown an alternative heat exchange structure generally indicated 210. The basis for the structure 210 is exactly the same as that for the structure 110 of Figure 3 and like features are indicated with light like reference numerals.

In this embodiment the structure 210 additionally includes diverter members 275 in the form of water impermeable membranes formed into a funnel arrangement towards the mouth of the channel 220 to maximise the amount of water collected from the ground above the channel 220. The diverters 275 may be connected to the channel 220 by any convenient means such as sealing tape (not shown).

Referring now to Figure 5 there is shown a heat exchange structure generally indicated 310 forming part of a heat pump system generally indicated 380 used for the heating or cooling of a building 390. The heat pump system 380 uses the heat exchange pipe 340 of the heat exchange structure 310 to provide heating or cooling of the building 390. Heat exchange fluid is circulated around the pipe 340 which forms a closed loop and interacts with heat exchange apparatus within the heat pump 380 to provide the heating or cooling effect.

The heat exchange structure 310 is of the same general type as that shown in Figure 3 and like features are identified by like reference numerals.

Referring now to Figure 6 there is shown an alternative heat exchange structure 410. The structure 410 comprises channels 420 arranged on the ground 435 and accommodating heat exchange pipes 440. The channels 420 are supported in a matrix of stones 455 on top of which are laid slabs 450 forming a permeable wear surface in the form of a pavement. The open mouths of the channels 420 allow rain water 495 which hits the pavement slabs 450 to drain into the channel and submerge the pipes 440. In this embodiment heat is transferred from heat transfer fluid in the pipes 440 into the water 445 in the channels, and then into the stone layer 455 and the ground 435 through the channels 420.

CLAIMS

1. A heat exchange structure comprising:
   - a substantially water impermeable channel for collecting water; and
   - one or more heat exchange pipes passing through the channel for carrying a heat exchange fluid.

2. A heat exchange structure as claimed in Claim 1, in which the channel is a subterranean channel.

3. A heat exchange structure as claimed in Claim 1 or Claim 2, in which the structure includes a substantially water impermeable trough member which comprises the channel or forms a liner therefor.

4. A heat exchange structure as claimed in Claim 3, in which the trough member is formed from a material having a high thermal conductivity.

5. A heat exchange structure as claimed in any preceding Claim, in which the channel contains particulate material.

6. A heat exchange structure as claimed in Claim 5, in which the particulate material comprises crushed rock.

7. A heat exchange structure as claimed in any preceding Claim, in which the channel is overlaid by a water permeable layer of particulate material.

8. A heat exchange structure as claimed in Claim 7, in which the particulate material comprises crushed rock.

9. A heat exchange structure as claimed in Claim 7 or Claim 8 when dependent on Claim 5 or Claim 6, in which the size of the particles overlaying the channel is greater than the size of the particles contained in the channel.

10. A heat exchange structure as claimed in any preceding Claim, in which a water permeable wear surface is formed over the channel.

11. A heat exchange structure as claimed in Claim 10 when dependent on any of Claims 7 to 9, in which the permeable wear surface is formed over the water permeable layer of particulate material.

12. A heat exchange structure as claimed in Claim 10 or Claim 11, in which the permeable wear surface comprises a pavement structure.

13. A heat exchange structure as claimed in any preceding Claim, in which there are provided a plurality of heat exchange pipes.

14. A heat exchange structure as claimed in Claim 13, in which the pipes are mutually spaced within the channel.

15. A heat exchange structure as claimed in any preceding Claim, in which the or each pipe is buried approximately 1.5 metres below the surface of the ground in use.

16. A heat exchange structure as claimed in any preceding Claim, in which there are provided one or more diverter members positioned above the channel for directing water into the channel in use.

17. A heat exchange structure as claimed in Claim 16, in which the directing members comprise sheets of water impermeable membrane arranged to funnel water into the channel.

18. A heat exchange structure as claimed in any preceding Claim, further comprising a unidirectionally water permeable layer positioned at ground level above the channel to prevent evaporation of water.

19. A heat exchange structure as claimed in Claim 18, in which the unidirectionally water permeable layer comprises a fabric.

20. A method of forming a heat exchange structure, comprising the steps of:

- providing a substantially water impermeable channel for collecting water; and
- passing one or more heat exchange pipes through the channel for carrying a heat exchange fluid in thermal contact with water in the channel in use of the structure.

21. A method as claimed in Claim 20, in which the channel is provided by forming a subterranean channel.

22. A method as claimed in Claim 18, further comprising the step of lining the channel with a trough member.

23. A method as claimed in any of Claims 20 to 22, further comprising the step of filling the channel with particulate material.

24. A method as claimed in any of Claims 20 to 23, further comprising the step of overlaying the channel with a water permeable layer of particulate material.

25. A method as claimed in Claim 24, further comprising the step of forming a water permeable wear surface over the channel.

26. A method as claimed in Claim 25 when dependent on Claim 24, in which the water permeable wear surface is formed over the water permeable layer of particulate material.

27. A method as claimed in any of Claims 20 to 26, further comprising the step of positioning none or more diverter members above the channel for directing water into the channel in use.

28. A method as claimed in any of Claims 20 to 27, further comprising the step of providing a unidirectionally water permeable membrane layer at ground level above the channel to prevent evaporation of water.

29. A heat pump system incorporating a heat exchange structure of any of Claims 1 to 19.

30. A building which is heated/cooled by a heat pump system according to Claim 29.

31. A subterranean heat exchange structure substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

32. A method of forming a heat exchange structure substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

33. A heat pump system substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

34. A building substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

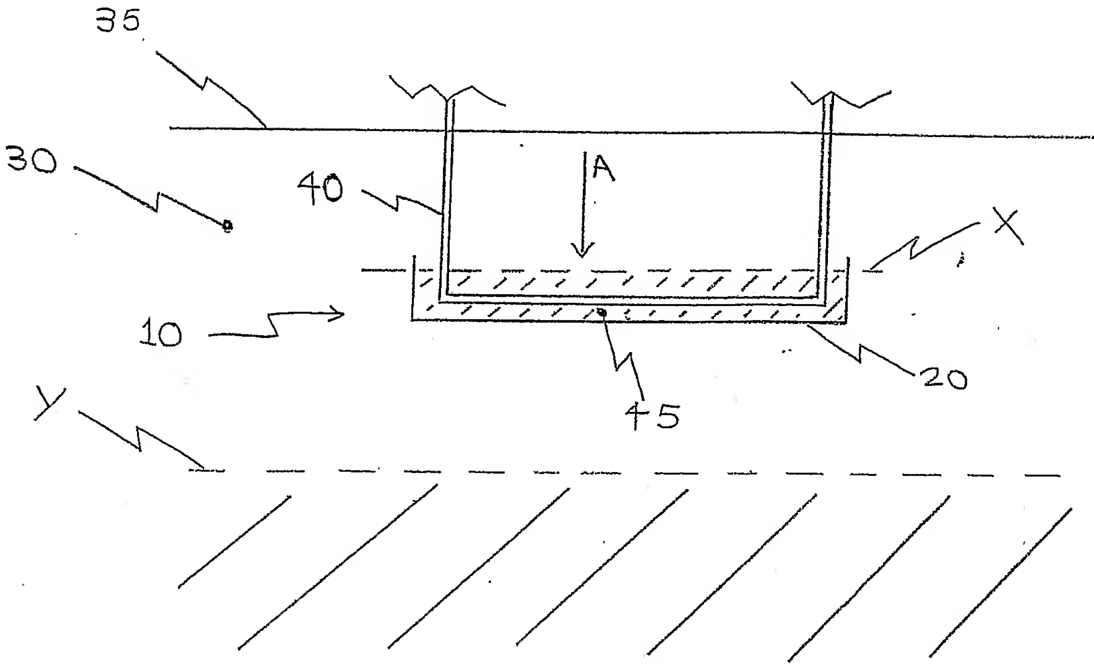

FIGURE 1

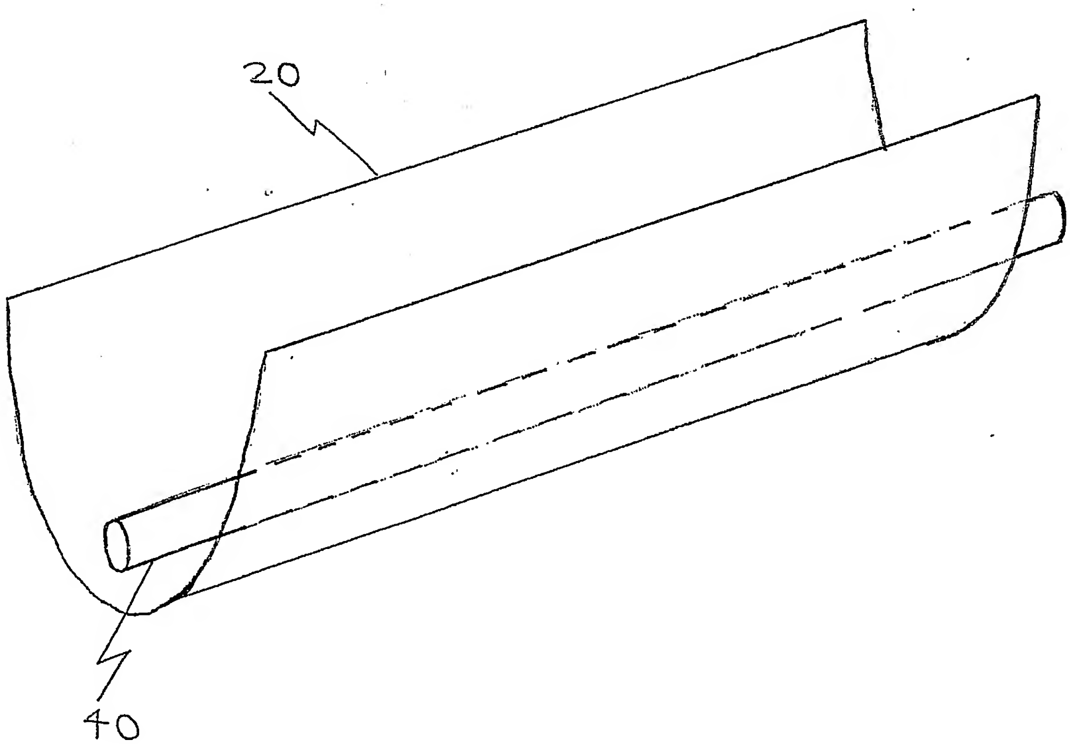

FIGURE 2

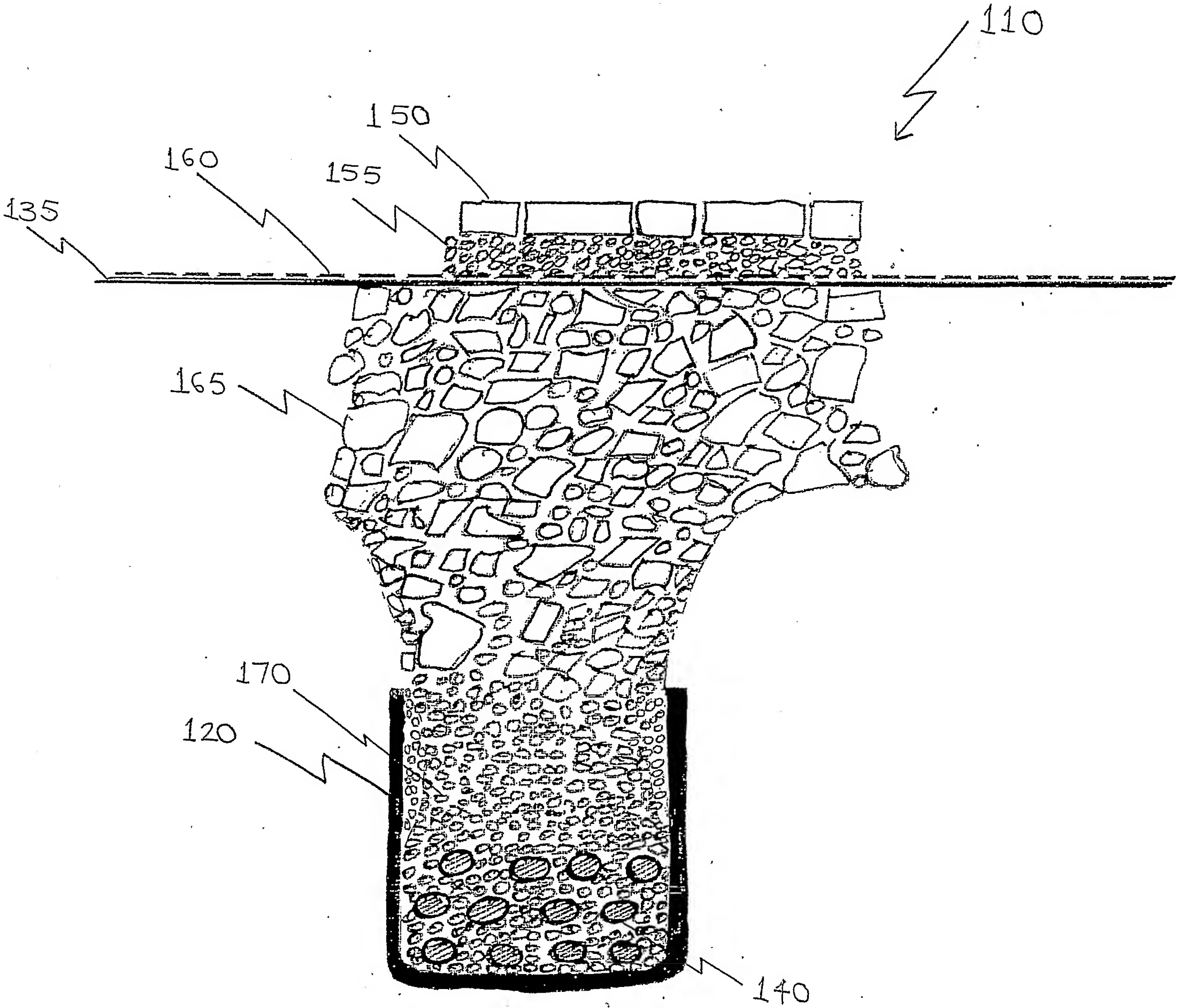

FIGURE 3

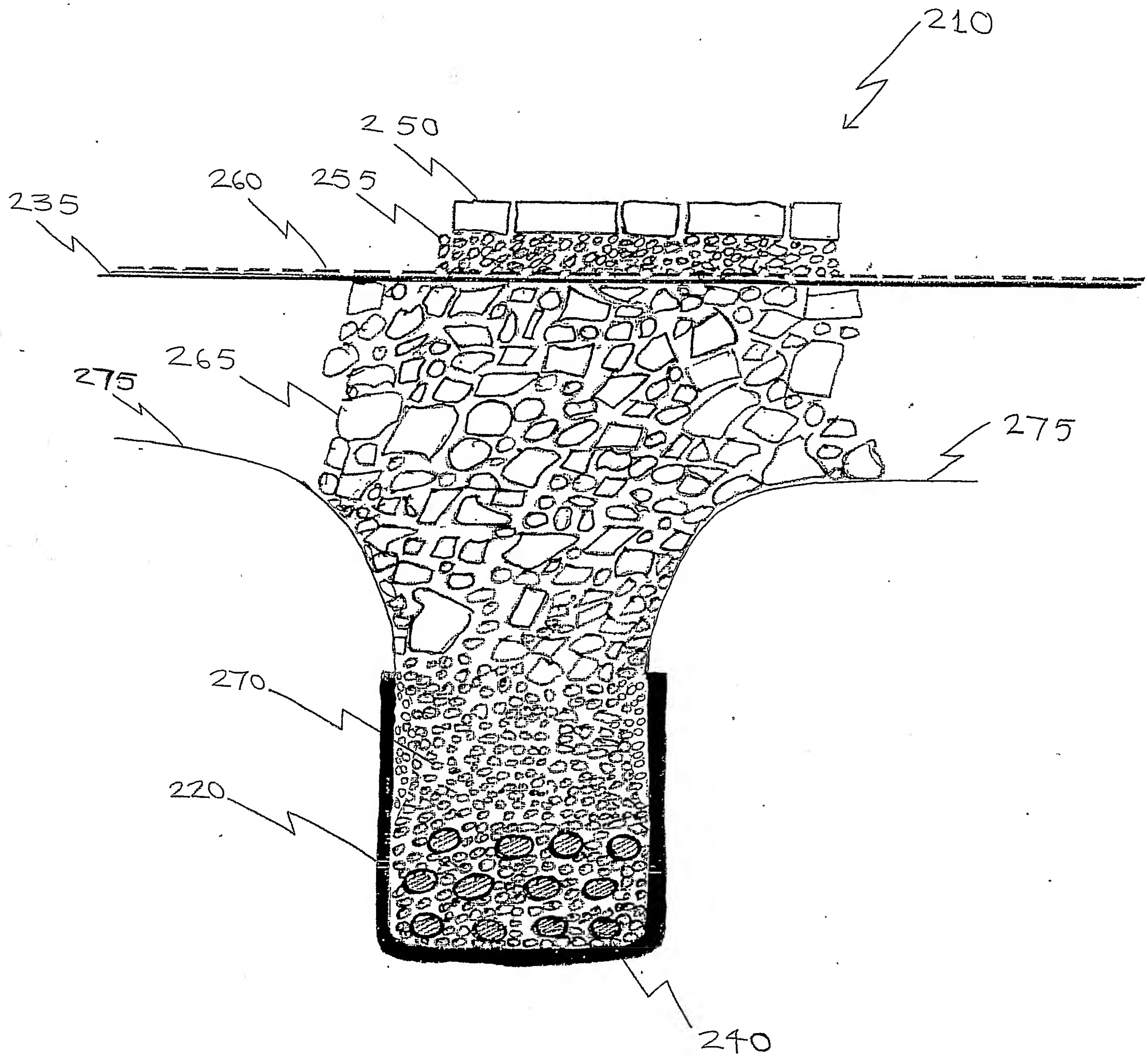

FIGURE 4

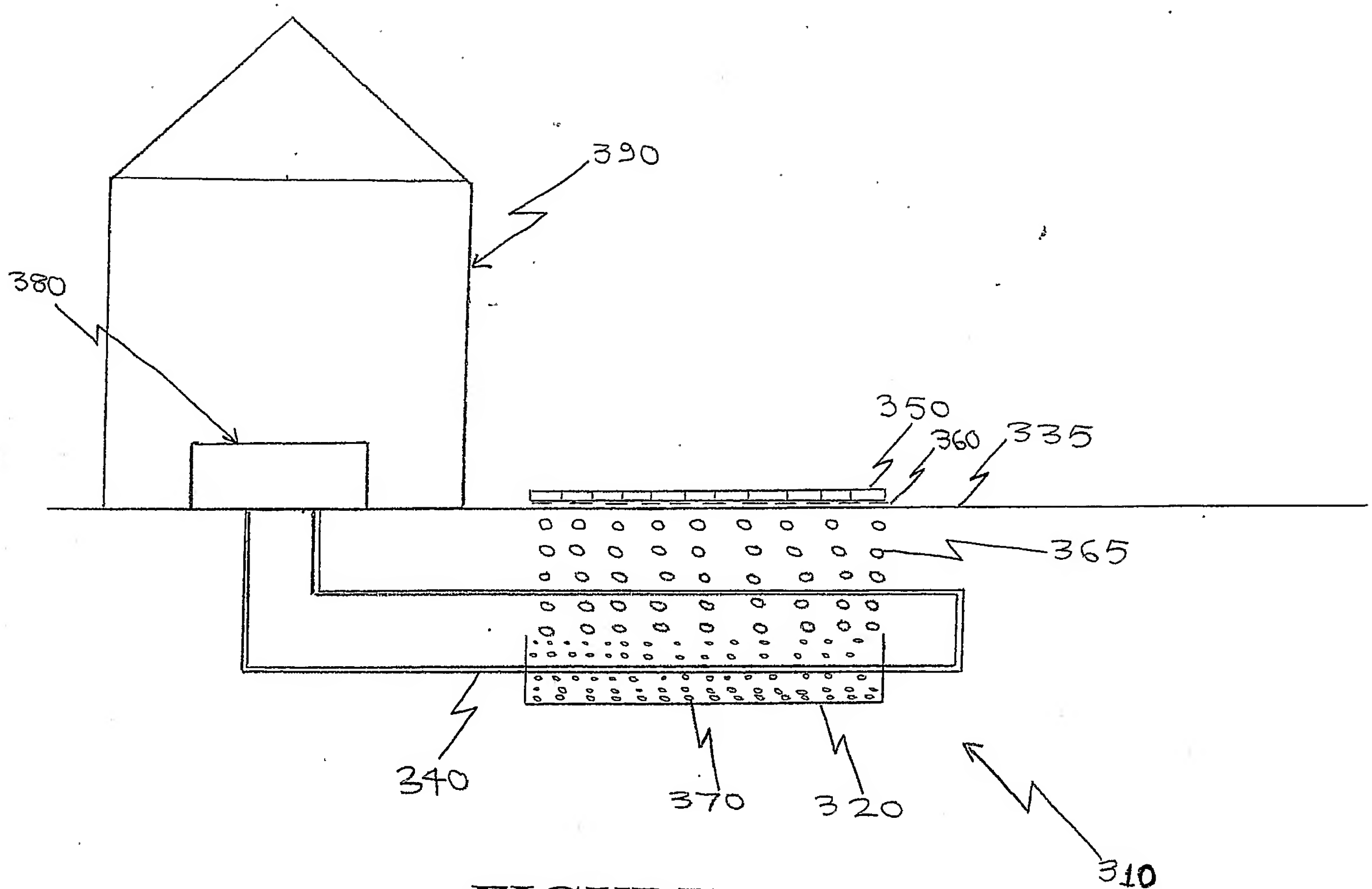

FIGURE 5

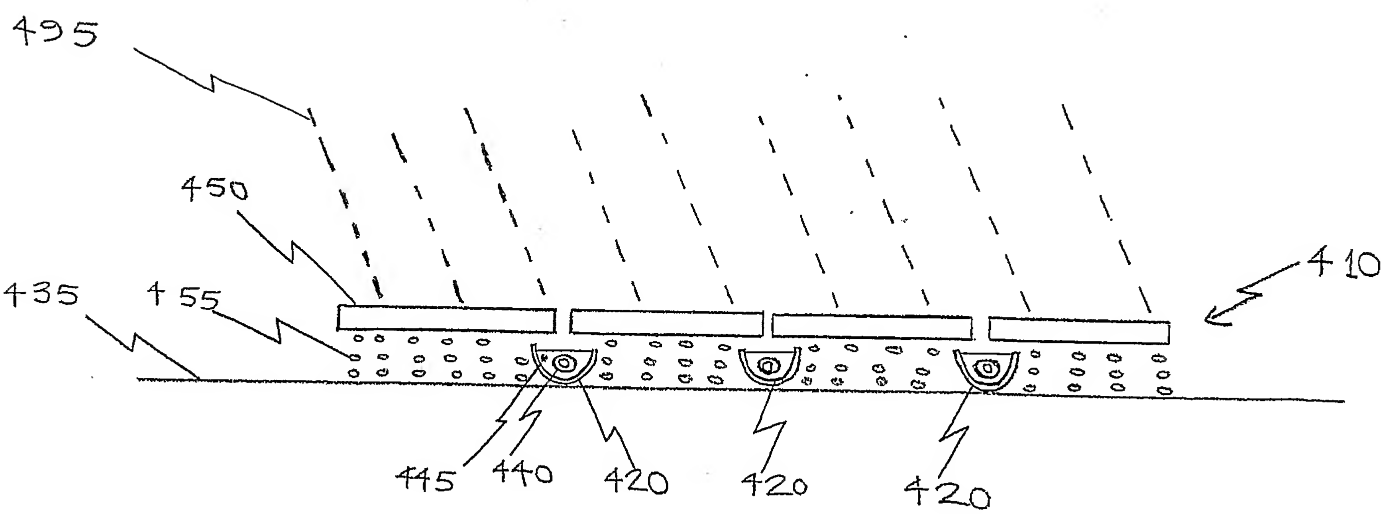

FIGURE 6